Experimental Educational Stand used for the Understanding of the Discharging Profile of Agro-Food Bulk Solids extracted by Geometric Variable Design Screw Feeders

Daniel C. Ola[1], Christian Fuerll[2] and Liviu Gaceu[1]
[1] Transilvania University of Brasov, Brasov, Romania
Email: danielola@unitbv.ro; gaceul@unitbv.ro
[2] ATB Leibniz-Institute for Agricultural Engineering, Potsdam, Germany
Email: cfuerll@atb-potsdam.de

***Abstract*— Screw feeders are devices suitable for handling a wide variety of bulk solids materials that have good flow ability characteristics and are often used as dosing feeders in food industry and agriculture. The manner in which material flows into the screw feeder affects the flow characteristics of the feeding hopper, the residence periods of the material in various locations in the bunker and thus the properties of the dosed material. The present paper will present some experimental results regarding the discharging profile of the mass flow screw feeders with variable geometrical design.**

***Index Terms*— Dosing screw; Mass Flow Hoppers; Flow Profile**

I. Introduction

The screw conveyor is one of man's simplest and most efficient transport systems for the bulk materials and is widely used in all fields of industry. Dosing screw conveyors are commonly used to extract bulk solids from the outlet slots of hoppers. The manner in which material flows into the screw affects the flow characteristics of the hopper, residence periods of the contents in various locations, segregation, attrition and torque requirements of the screw. Motion regimes of the bulk solids in various sections of the equipment are outlined and a simple qualitative analysis enables predictions to be made based on material factors and screw dimensions.

Shortly, the advantages of the horizontal screw devices are: reduced risk of environmental pollution, the transported material is protected from exterior contamination, flexibility of use, functional reliability, easy to install, easy to clean, can control very well the flow of free flowing materials [1].

The disadvantage is mainly linked to the poor mechanical transport efficiency and the low protection of the screw flight against objects that can be tapered in the screw clearance with the chamber [1].

There are 4 major types of dosing screw feeders according with their constructional characteristics:
- screws with uniform pitch and diameter;
- screws with gradual pitch;
- screws with gradual diameter (taper diameter screw flight, taper shaft).

II. Flow Pattern of the Dosing Screw Feeders

A. *Constant Pitch and Uniform Diameter Screw Feeders*

These are considered to be the most economical screws to manufacture and they are widely used in systems that run at low rotational speeds. This type of screw (figure 1) will fill with material only the first one or two pitches, the rest of the feeder length will not extract material developing above it a region of static material so called a stagnant flow [1].

The disadvantage of these systems is that the portion of screw that runs under the stagnant material region is under larger shear stresses and therefore absorbs more torque power to rotate and will have a greater impact upon the material leading to important altering of the physical properties for the material found in that region. From the quality point of view of the materials being dosed by this kind of systems is considered that this solution does not provide similar fed material properties, as the material in the stagnant region will change it's properties as it requires a longer time to be extracted and is under bigger consolidation forces due to the movement of the screw feeder and of the bulk pressure

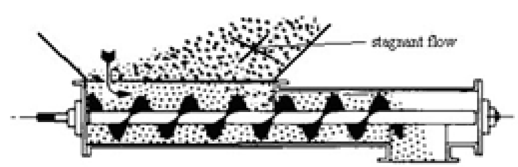

Figure 1. Schematic representation of the material extraction for a constant pitch and diameter dosing screw feeder [1].

The construction parameters are constant pitch in the feed section and larger constant pitch in the conveying section. Usually the pitch of the screw feeder is designed to be about two thirds of the diameter value in the feed section, and equal with the diameter in the conveying section. Larger values are consider to lead to poor transport efficiency [1].

B. *Variable Pitch Screw Feeders*

These types of screws (figure 2, b) can provide increasing extraction capacity by starting with a short pitch of the flights and progressively increase the pitch to the maximum capacity.

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For short distances they can achieve a continuous bulk solids flow though the capacity of each increment depends on the transfer capacity of each screw flight pitch. The larger the pitch the better extraction and therefore the minimum pitch must be no less than one-half the screw diameter and the maximum pitch should be about the screw flight diameter.

Figure 2. Picture of the 4 types of screw feeders used in the experimental research . a - constant pitch and diameter dosing screw feeder; b - variable pitch screw flight feeder; c – tapered diameter screw flight feeder; d – tapered shaft screw feeder.

C. Tapered Diameter Screw Flight Feeder

Another way to provide a mass flow in the extraction of bulk materials is to taper the screw flight diameter (figure 2, c), starting with a small diameter and increasing it to a maximum value. The pitch of the screw flights is constant along the length. This is not a very used method since most materials tend to arch above the narrow section of the screw flight and this technical solution it is very difficult to manufacture and therefore it is very expensive.

D. Tapered shaft screw feeders

The taper shaft screws (figure 2, d) develop the mass flow extraction from the feeding bin by assuring a progressive extraction along the axis since the screw diameter starts from a maximum value in the section of the first screw flights and gradually decreases until it reaches the minimum value which is equal with the maximum output of the screw [2]. This solution is an adequate method for producing a mass flow of the material extracted but the fabrication tolerances are a frequent problem and the costs are also quite expensive. Dead regions in the flow of material will have as consequences the uneven residue periods and unwanted deterioration of the flow properties in the flow of the static material. It is expected that the flow profile of the mass flow dosing screw systems for bulk solids, to behave as presented in figure 3. It can be observed that these dosing screws will entrain all the bulk material found in the hopper outlet above the screw feeders, leading to the dosing of the bulk solid without forming of stagnant flow regions above the screw.

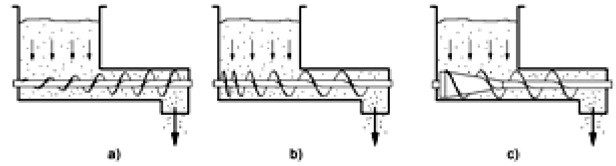

Figure 3. Schematic representation of the expected uniform material extraction from the hopper outlet by using variable geometry dosing screw feeders. a – extraction using a tapered diameter screw feeder; b – extraction using a variable pitch screw feeder; c - extraction using a tapered shaft screw feeder.

Since the density is sensitive to states of stress during flowing, the precision of the output dose flow is dependent on the uniform characteristics of the bulk solids in the hopper outlet to the dosing screw. By installing the proper agitation device, a constant state of fluidization and so of bulk density can be obtained, assuring in this way the uniform characteristics needed for a constant extraction flow.
In order to guarantee the mass flow from the silo, the width of the hopper may be only a little larger than the diameter of the screw feeder. In particular, for conical screws the chamber should be accordingly designed.

III. Experimental Methods used in the Extraction Behaviour of the Variable Screw Feeders

For the experimental analysis of the flow profile of the mass flow screw feeders with variable geometrical design, an experimental dosing stand (figure 4) was developed which provided the monitoring of the free bulk solids surface that was discharged from the feeding bin of the dosing stand according with the characteristics of each screw feeder.

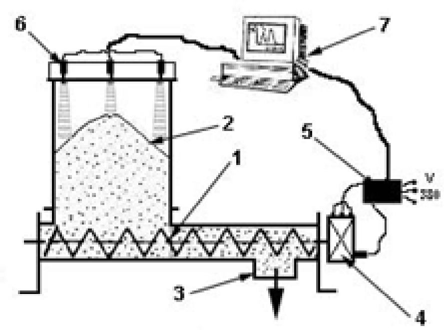

Figure 4. Dosing stand with horizontal dosing screw feeders with variable geometry : 1 – interchangeable dosing screw feeder; 2 – feeding bin for material in bulk solids; 3 – evacuation area; 4 – driving group provided with sensor of rotating speed; 5 –frequency variator for automatic adjustment of the rotating speed of the electric motor; 6 – ultrasound level sensors.

The dosing stand is powered by a three phase electric motor with 1,5kW power. The driving of the screw feeder is made through a chain transmission with a transmission ratio of i = 2,28.

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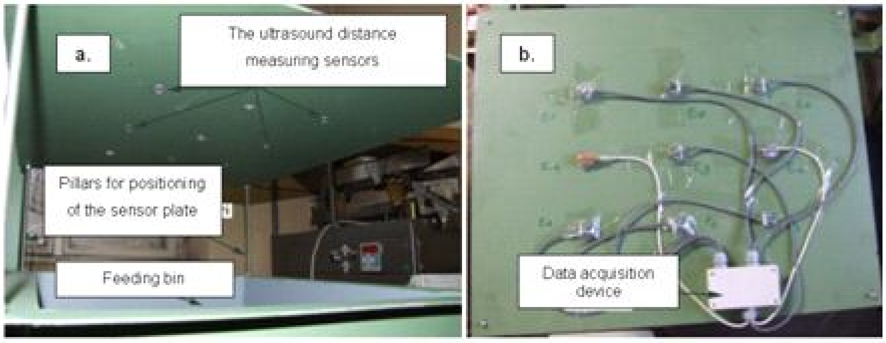

Figure 5. Assembling of the distance ultrasound sensors and positioning of the sensors in order to determinate the free surface of the extracted material from the feeding hopper. a – general view of the 9 sensors directed towards the material; b – view with the sensor's indicative codes and their connection to the data acquisition device.

The electric motor is powered through an frequency variator made by Hitachi type SJ100 030HFE that can provide a maxim load of 3,5 kW. The dosing chamber is made out of a steel tube with a internal diameter of 140 mm and a length of 830 mm and is custom made accordingly with the German standard DIN 15262. The inlet and outlet areas of the bulk solid are of rectangular section in order to study the most comonly used situation in industry. At both ends of the dosing chamber there are easly changeble ball bearing flanges that allow for a quick acess for changing the screw feeders.

The feeding bin (fig.) is made out of steel sheets that are coated with a wear resistant paint, has a 0,2 m^3 capacity and a rectangular cross section. The shape of the bin was choosen to prevent the formation of arching of the material above the screw feeders especially since the dosing stand has no agitating devices. The dosing screws used in experiments have a total length of 1080 mm, with the following characteristics:

- constant pitch and diameter screw feeder (fig.2, a): screw flight diameter 125 mm, screw flight step 100 mm, screw flight shaft 40 mm, screw flight thickness 1,5 mm.

- variable pitch screw feeder (fig.2, b): screw flight diameter 125 mm, screw flight shaft 40 mm, with four progresive screw flight steps in the extraction area and a constant 100 mm step in the trasport area of the screw, screw flight thickness of 1,5 mm;

- tapered diameter screw flight (fig.2, c): the screw flight diameter starts at 45 mm and reaches 125 mm on the extraction area, screw flight step 100 mm, screw flight shaft 40 mm, screw flight thickness 1,5 mm;

- tapered shaft screw feeder (fig.2, d): screw flight diameter 125 mm, screw flight shaft gradualy deceeses from 120 mm to 40 mm in the extraction area, screw flight step 100 mm, screw flight thickness of 1,5 mm;

The monitoring of the free surface of the bulk solid was made using distance measuring ultrasound sensors (figure 5) that were positioned on 9 evenly spread points on the surface of the sensor plate mounted on the top of the feeding bunker. By graphic representation of each set of measurements in the shape of a surface generated by using the 9 points of measurements, the experimental stand allowed the representation of the material free surface during the discharge, providing in this way a comprehensive insight upon the way the screw geometry affects the flow of the material.

IV. Presentation of the Obtained Results

Because of the complexity of the pressure state inside the material it is difficult to analyse or investigate the conditions in the extraction area of the screw chamber inlet, but from the point of view of the material extraction manner from the feeding hopper by analyzing the free surface of the material there can be observed the way in which the material flows according to each type of dosing screw feeder.

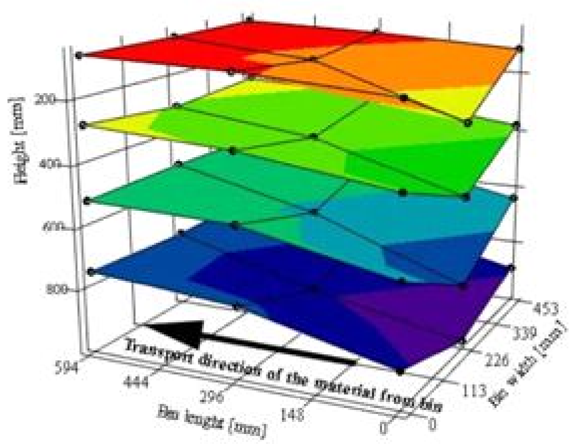

Figure 6. Flow profile of material discharged characteristic in the case of the dosing screw feeder with constant geometry.

For example for the dosing screw feeder with constant geometry the extraction pattern is made mainly from the area of the first screw flights of the dosing screw feeder (fig. 6) while above the rest of the screw flights the material stagnate and flow only when the right side of the hopper has a sufficient depth to exceed the natural slope angle of the material. For the case of a uniform extraction and without mixture of the material from the feeding hopper of the dosing unit, there was studied the profile generated by the dosing screw feeder with variable pitch and constant diameter of the screw flight, resulting the form of the extraction profile presented in figure 7.

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The material extraction profile from the hopper along the dosing screw feeder exposed in the material area is in compliance with the incremental extraction manner of each dosing screw feeder with variable geometry but being strongly influenced by the material characteristics to flow freely or under the form of some rat holes generated manly above the first pitch.

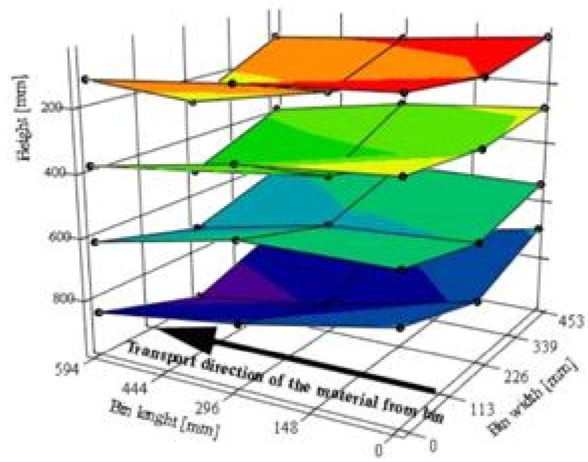

Figure 7. Flow profile of material discharged characteristic in the case of a screw feeder with variable pitch and constant screw flight diameter.

The material free surface area showed increased depth especially in the region were the screw intake capacity was larger and the possibility of material arching above the screw was minimum thus shifting the main extraction zone to the left of the feeding hopper. Studying the extraction profile of the bulk material extracted by the dosing screw feeder with constant pitch and variable diameter of the screw flight (figure 8) of the dosing screw feeder a flow profile was generated

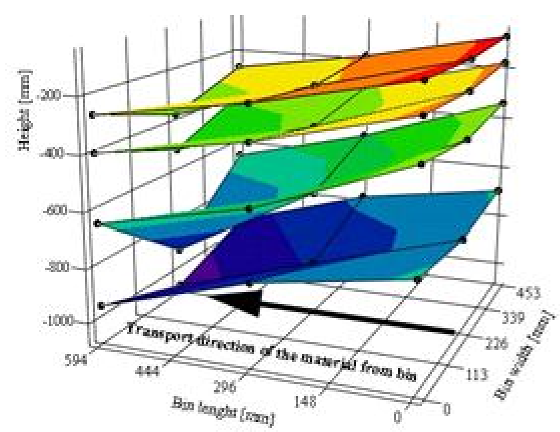

Figure 8. Flow profile of material discharged characteristic in the case of a screw feeder with variable screw flight diameter and constant pitch.

that presents the movement of the main flow area towards the left area in the direction of transport of the dosing screw feeder, region were the diameter has the maximum value and the best undertaking capacity. The material extraction profile generated by the dosing screw feeder with the variable diameter of the shaft and the constant pitch of the screw flight, was similar with the extraction profile from figure 7 with increased material undertaking characteristic in the area of the screw where the extraction capacity was maximum.

Therefore, the flow profile presents a movement of the main flow area towards the extraction area of the dosing screw feeder in which there is the smallest diameter of the shaft and thus a bigger undertaking capacity due to the increase of the diameter of the screw flight of the dosing screw feeder. The experiments made with the tapered shaft screw flight feeder were not relevant since the small extraction capacity of the tapered screw flight created material bridges above the screw resulting into a stagnant flow region for the material and showed similar results with the ones made for the variable screw flight diameter and constant pitch screw feeder.

Conclusions

The graphic results provide important data for the flow behavior of the different materials and their flow stagnation times according with the type of the mass flow screw feeder used. As it can be seen from the two graphic representations of the discharge phases from figures 7 and 8, the location of the major flow in the bulk solid mass has shifted from the right side of the bin, in the case of the screw with constant geometry, to the left side and the middle of the bin due to the bigger outtake capacity of the last pitches of the screw with variable geometry because of the materials' modality to fill more efficiently the big extraction volumes as compared to their difficult flow in smaller spaces and volumes of the first screw flights.

This experimental stand can provide important data aspects regarding the residence periods of the bulk material inside the feeding bin and were are the locations of insufficient flow were flow enhancement devices should be used, important in the food industry where it is aimed to achieve uniformity in the quality of the dosed products by reaching uniform times of material feed from the feeding hoppers.

References

[1] Bates, L., Entrainment pattern of screw hopper dischargers, Trans. ASME, J. Eng. Ind. 91B, (1969) 295-302.

[2] Vollmann, A.: Untersuchung der Schüttgutförderung in geneigten Schneckenförderern. Dissertation TU München, 2000.

[3] Schumacher, W., Zum förderverhalten von bunkerhalten von bunkerabzugsschnecken nit vollblattwendeln, Doctoral thesis, Rheinish-Westfälishen Technischen Hochschule Aachen, 1987.

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